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Comprehensive Disposal of Decommissioned Vehicles

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Abstract

The article concerns the final stage of the life cycle of vehicles (on the example of Russia). The purpose of the study is to develop an organizational scheme for the gradual creation of a unified system for the disposal of all types of vehicles that are out of service. The study included a legal, technical, and territorial analysis. For territorial analysis, statistical data were taken for the following types of transport: buses, trucks and cars. The result of the work is the division of recycling enterprises by recycling levels, namely, the use of classification A, B, C, D. Recycling centers organization is usually considered within the Federal districts, which will lead to the dispersion of recycling capacities throughout Russia. The Federal district will have a radical ring system of organizing recycling centers at different levels. The State should create a unified recycling system with the adoption of regulatory documents on the interaction of participants in the disposal of vehicles, it should involve commercial organizations in recycling activities in future. The prospects of the study suggest 3 options for the placement of warehouses and recycling centers for their effective operation and address the issue of recycling of highly specialized transport.

Keywords: Disposal; Recycling; Decommissioned Vehicles; End-of-life Vehicles; Recycling System.

1. Introduction

The developed countries have been addressing the issue of recycling various vehicles for quite a long time. Each country has its own individual methods of solving this problem and its own set of priority transport for disposal. The Russian vehicle recycling system is at an early stage of development, where its basic principles have not yet been developed, and there is no general structure of the system.

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Russia has the widest possible range of transport in connection with the country's needs, which adds some difficulties to the development of a policy for vehicle recycling. Today, a number of researchers have already developed organizational and technical solutions for the disposal of the most popular transport-passenger cars. In Russia in 2017, more than 22 million passenger cars with a service life of more than 10 years were registered. Some of the recycling solutions for passenger cars are also applicable to other types of vehicles, since they share the same structural features and use the same materials in production. At the same time, some types of transport have global and disparate differences that complicate the entire recycling system.

Thus, it is proposed to create a comprehensive large-scale recycling system for all types of transport in Russia as soon as possible. Every year, the volume of vehicles that are out of service increases, which makes the situation worse. The unified system will allow to" pull up " to the recycling process vehicles that are not a priority and do not have significant statistics on decommissioning. However, these vehicles, like others, are harmful to the environment and contain materials that can be recycled and reused.

Using the example of passenger cars, we will consider the main factors that accelerate the process of decommissioning vehicles. The policy of the automotive industry is aimed at increasing the commissioning of new vehicles and reducing the actual use of the vehicle (this is how the manufacturer's lifecycle management currently looks like). Cars in Russia have become more accessible due to the full production and assembly of foreign brands on the territory of Russia, also, special car loans, state benefits and opportunities to use the trade-in service.

The factors that prevent the organization of the process of putting vehicles for recycling are the lack of:

- the standard of conduct for a vehicle owner who wants to dispose its vehicle;
- a clear and accessible system for the disposal of vehicles;
- comprehensive recycling system that can handle all types of waste;
- a direct economic mechanism for implementing the recycling system, neither by the vehicle owner nor by the recycling company (except for tires) (Kosacka-Olejnik, 2019).

The recycling system should be implemented by the State, or at least create conditions under which there will be a benefit for enterprises, responsible for recycling. The state should also introduce a motivational program for vehicle owners. The motivational program should be aimed at excluding the use of vehicles that do not correspond to the operating conditions.

In Russia, the final stage of the vehicle Life cycle is currently in a problematic state. The stage itself can be implemented on the basis of one of four strategies, each of which has its own waste management technology:

- the first strategy is prevention, which is aimed at reducing the possible formation of waste at the early stages of their formation.
- the second strategy involves the action of 3 aspects (R3WE):
  - recycling and reuse of materials;
  - waste recovery for reuse;
  - use of waste for energy production (heat and hot water).
- the third strategy (recycling) refers to waste, the formation of which can not be excluded. The main objective of the strategy is waste recycling and reuse;
- the fourth strategy (disposal) is to preserve waste that cannot be disposed of or recycled due to the lack of technology or material characteristics.

All the principles and strategies are known. But there is no organizational solution to implement these strategies. Obviously, the first step should be to determine the organizational structure of the recycling system.

2. Method of Research

The paper uses a legal, technical and territorial analysis that allows for the obvious problem of recycling to identify and specify the primary tasks for a comprehensive recycling system and identify possible solutions in terms of the territorial location of enterprises for the recycling of vehicles.

2.1. Regulatory Analysis

For the successful operation of the recycling system, there must be a regulatory component that can regulate all stages of recycling and the actions of its participants. Depending on the policy of the State and the development of industry in each individual country or group of countries, the norms and legal acts differ.

In the EU countries the Directive 2000/53/EC acts since 2000, which outlines waste management automotive industry: the collection and recycling of vehicles, the ability to reuse parts and components, restoration, standardization and exchange application of necessary information to improve recycling activities (Despeisse et al., 2015; Kie et al., 2016).

The main distinctive feature of the recycling system in the EU countries is that it is an independent commercial activity, and recycling is the responsibility of the manufacturers themselves (Kie, 2017).

Manufacturers must also:

- reduce the amount of dangerous substances in the production of automobiles;
- develop and design vehicles in a way that makes disassembly easier in the future;
- try to use materials with possible reuse and inform recycling companies about their use;
- mark parts according to the generally accepted classifier;
- develop a recycling and utilization process for each vehicle they produce.

The highest utilization rate is 96.2% and it was achieved in the Netherlands in 2011. The recycling tax is 45 euros and is paid when a new car is purchased by its first owner. Subsequently, after the vehicle is out of service, the owner does not pay for any additional funds.

As for imported cars, for example, in Finland, the importer and official dealer are responsible for recycling.

In Russia, the recycling fee for vehicles manufactured on the territory of the country, as well as for those imported into the Russian Federation, was introduced on September 1, 2012 by Federal law No. 128-FZ of 28.07.2012 "On amendments to the Federal law "on production and consumption waste" and article 51 of the Budget code of the Russian Federation".

The main difference between the recycling tax on vehicles in Russia and foreign countries is that since January 1, 2014, the recycling fee is paid by manufacturers, exporters and individuals, if no one has previously paid tax for this car.

2.2. Technical Analysis

The state policy of comprehensive recycling implies the utilization and recycling of all types of vehicles, so we note that vehicles of different types of transport have huge differences from each other in size, weight, design, materials used, and additional equipment.

Table 1 shows data on the mass of waste of Russian-made passenger cars by type of materials.

Table 1. The weight of waste.

Material	Mass of waste, recyclable, kg	Share, %
Ferrous metals	682	66.02%
Nonferrous metals	47	4.55%
Glass	31	3.00%
Tyres	39	3.78%
Rubber	14	1.36%
Plastics	79	7.65%
Natural and organic materials	31	3.00%
Adhesives and mastics	17	1.65%
Paintwork material	18	1.74%
Gasoline	3	0.29%
Antifreeze	7	0.68%
Engine oil	3	0.29%
Transmission oil	2	0.19%
Other	60	5.81%

When processing heavy cargo vehicles or railway wagons, the material structure will differ significantly.

Table 2 shows the results of calculations of utilization and recycling coefficients of cars of the domestic brand "LADA".

Table 2. Results of calculations of coefficients of utilization and recycling of cars of the domestic brand " LADA».

Make and model of car	The recycling rate	The utilization coefficient
LADA KALINA	0.871	0.978
LADA PRIORA	0.854	0.973
LADA 4X4	0.88	0.99

However, the data presented in table 2 is averaged, since vehicles of the same model and the same year of production may have different disassembly technology for some components. When selling a car, the buyer can choose the complete set of the vehicle with the necessary characteristics, which means that some components may be completely different on vehicles of the same model, or not at all. Therefore, some parts of the same car model and brand can be disposed of using different technologies and strategies for the final stage of the Life cycle. In EU countries under Directive 2000/53/EU, car manufacturers are required to mark the main components and parts of the vehicle according to the universal classifier (Rosa and Terzi, 2018).

Based on the technical analysis of vehicles, it should be concluded that the vehicle recycling system requires specialized workshops for processing and recycling of specific types of materials. The production capacity for processing a specific material should be calculated based on the percentage of the total waste.

For example, if recycling concerns passenger cars, the maximum production capacity should be set for the processing off ferrous metals.

2.3. Territorial Analysis of the State of Vehicles in Russia

For the territorial distribution of utilization capacity, it is important to understand the location of demand for each type of transport, where there will be an accumulation of decommissioned vehicles. If we consider passenger cars, most vehicles will be operated on the territory of their registration link. Even after resale-the transfer of transport from one owner to another, registration of the vehicle often takes place in the region where the owner will live. The owner who registered the vehicle is ultimately responsible for delivering the vehicle to the recycling center. It can be assumed that the maximum number of cars that have fallen into disrepair will be formed in the cities, regions, and regions where they are registered.

Similarly, it is possible to determine the concentration of public transport after release from service. Data for public transport will be more accurate than for passenger cars. Routes and the period of use of public transport are strictly regulated and monitored, so the number, place and time of failure of buses, trolleybuses, trams and metro cars can be predicted, which will make it possible to determine the geographical location the recycling capacity.

The most difficult situation is with cargo transport, the movement of which is as chaotic as possible over the entire period of operation and may be irregular, which makes it difficult to calculate the exact time of vehicle decommissioning. Concerning the territorial accumulation of cargo transport after the useful life, it should be noted that the deregistration and the transfer of cargo transport to the disposal will take place after the issuance of the preparation mechanics in a garage-park of organization.

Table 3 shows data on the number of different vehicles in Russia by districts.

Table 3. Number of vehicles for 2018 in Russia by districts.

Federal district	Passenger car	Structural share, %	Buses	Structural share, %	Cargo vehicles	Structural share, %
Central federal district	12483560	29.7	30141	29.82	149304	25.16
North-Western Federal district	4398140	10.47	12181	12.05	51980	8.76
Southen Federal district	4326391	10.29	12971	12.83	69063	11.64
North Caucasus Federal district	2111597	5.02	5311	5.25	22552	3.8
Privolzhskiy federal district	8806933	20.96	17465	17.28	128106	21.59
Ural federal district	3920983	9.33	9737	9.63	62988	10.62
Siberian federal district	4737066	11.27	9612	9.51	72126	12.16
Fareasten federal district	1241372	2.95	3671	3.63	37182	6.27
Total	42026042	100	101089	100	593301	100

* Calculated on the basis of data of the Federal State Statistics Service, https://www.gks.ru/free_doc/new_site/business/trans-sv/trans_gaz.htm.

The largest concentration of all transport vehicles are located in the Central and Volga Federal districts. According to the average value of the structural shares of each type of transport shown in table 2, the southern Federal district occupies the third place in terms of the number of vehicles. The structural distribution of all three types of vehicles is almost identical. The concentration of vehicles is observed in the Central part of the country, as evidenced by the developed transport infrastructure in these regions. Therefore, the maximum utilization capacity should be present in these Federal districts.

Figure 1 shows a color-coded map of Russia showing the Federal districts with the largest number of registered buses, trucks, and passenger cars.

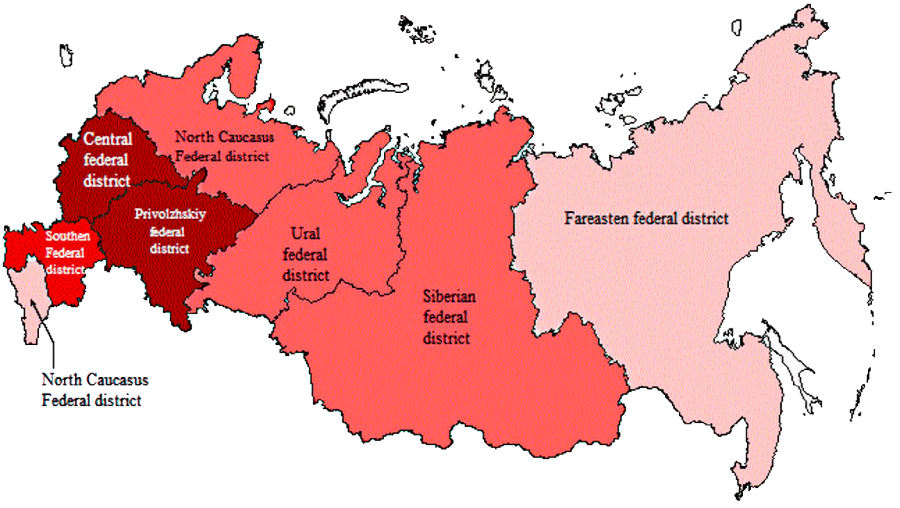

Fig. 1. Federal districts with the largest number of registered buses, trucks, and cars.

It is advisable to link disposal companies to Federal districts. In this case, disposal facilities will be dispersed throughout Russia. Based on the results of the territorial analysis, we note that the largest amount of utilization capacity should be concentrated in the Central and Volga Federal districts, and the smallest - in the North Caucasus and far Eastern Federal districts.

It is possible to exclude the location of utilization and recycling facilities in the North Caucasus Federal district due to the small number of vehicles and proximity to the districts where the maximum utilization capacity will be concentrated.

The construction of enterprises for recycling vehicles in the far Eastern Federal district can not be excluded because of its large area and the prospects for the development of the transport industry in this territory. The nearest recycling facilities may be located quite far away, which will create additional difficulties and costs for logistics of vehicles that are out of use.

Technical analysis requires the creation of a system of recycling centers with different levels of recycling. The location of the main recycling centers can be calculated using the graph-geographical model of the region proposed in, which is a flat graph with marked vertices and edges. The vertex potential is calculated using the formula:

$$P_i = w_1 * \alpha_1 * N_i + w_2 * \alpha_2 * Z_i + w_3 * \alpha_3 * K_i \quad (1)$$

N_i - population at point V_i;
Z_i - the average salary of the population at point V_i;
K_i - the number of vehicles per 1000 people at point V_i;
w_1, w_2, w_3 - weighting coefficients;
α_1, α_2, α_3 - normalizing coefficients.

This barycentric model was applied to design within the region, but it can be applied to districts and the country as a whole (Kuznetsova et al., 2018).

At the initial stage, the State should take over the creation of the recycling system and build a regulatory framework that will clearly regulate the attitude of participants in the recycling system. After its adoption and all the necessary conditions creating, it is possible to move to attracting commercial organizations to build recycling centers.

3. Research Results

The result of the study is the decision that recycling enterprises should be divided by recycling levels, so recycling enterprises can be classified into classes A, B, C, D.

Class A means a major recycling company, providing solutions to a full range of tasks of the disposal system and implementation of high-intensity interactions of all interaction flows, the execution of unique and complex projects related to the development of solutions for the recycling properties of an object at all stages of the lifecycle.

Class B refers to large recycling companies that provide solutions to the full range of recycling system tasks and implement the majority of interaction flows, and are local players in the market.

Class C refers to specialized recycling companies that perform a certain segment of recycling work and produce a narrow list of secondary materials that have the highest demand on the market.

Class D - receiving points, specialized in issuing certificates for recycling and providing transportation services; materials are usually processed by third-party organizations.

Consideration of the organization of the entire range of classes of the system will be held geographically within the Federal districts. For example, the Federal district will have a radial-ring system for organizing recycling centers at different levels. Class A enterprises will be located in the center, and class B, C, and D centers will be located around the circle.

To build an effective vehicle recycling system, it is also recommended to divide recycling companies into groups and, if necessary, introduce subgroups. For example, dismantling and shredding enterprises can be divided into groups by type of vehicle, and specialized enterprises - for processing specific types of materials for all vehicles (for example, for tires, plastic, etc.) (Zhang and Chen, 2018).

Due to this versatility of the organization, the processing enterprises will have the maximum unification of production, which will reduce the cost of processing and recycling of vehicles, and it will be possible to use the same equipment with tools for dismantling and subsequent recyclable technological operations (Kuşakcı et al., 2019; Pietroluongo et al., 2019; Xiao et al., 2018).

In vehicles of the same type, the same materials prevail, so the efficiency of sorting and processing will be increased at enterprises where specific types of vehicles are dismantled and crushed (Saidani et al., 2017).

Also, with such an organization of enterprises, it is possible to build additional centers for checking entire parts, assemblies and aggregates, which can be re-used without technological processing.

We should not forget about highly specialized vehicles that are used in various industries. Examples in the agricultural sector are combines and tractors, in the mining industry-dump trucks, etc. Manufacturers of specialized vehicles should work out the issue of recycling and find the analog recycling system for more similar vehicles in terms of dimensions and material structure.

The chosen organizational scheme implies a combination of interaction between large enterprises and small ones within the districts, which will make it easier to dispose of vehicles of private owners, who will be able to hand over their cars within a 30-50 kilometers zone from their place of residence. The comprehensive recycling system, organized within the district's will create new jobs not only in the Central part of Russia, but will also help improve the economic situation in other regions of the country and not only in large cities, but also in small ones.

4. Discussion and Research Prospects

The study predicted an annual increase in the number of vehicles that are out of service, which requires large areas for storage, which is only possible on the outskirts of megacities or in small cities where it is possible to place warehouses. There are three options for placing warehouses and recycling centers for their efficient operation.

The first option involves the location of warehouses and recycling centers on the outskirts of the metropolis, which will allow you to have large areas that can be expanded if necessary, take into account the wind rose to reduce emissions to the city and reduce the risks of a lack of qualified personnel and the necessary number of employees.

The second option involves the location of warehouses and recycling centers on the territory of a small satellite city near the metropolis. This option implies solving problems with warehouses and reducing the daily flow of workers in the metropolis, by creating new jobs in nearby cities. However, if there is a shortage of labor or specialists, it is possible to attract them from a nearby city of one million people.

The third option involves the location of warehouses and recycling centers on the territory of nearby single-industry towns, where there is transport infrastructure and idle production facilities, which can be filled with tasks for the disposal of vehicles. The choice of such a territorial location is due to the fact that there is a necessary area for the construction of a recycling center and warehouses. A sufficient number of employees will be recruited from small towns that are located next to each other. The third option is aimed at improving and maintaining the socio-economic situation in cities with a small population.

In Russia for several years is going recycling tax, but there is no enough amount of the built utilizing modern enterprises. There are not responsible persons for the disposed vehicle end-of-life, the number of which is growing every year.

The creation of a recycling system must begin with the approval of the relevant authorities. The question remains whether the State will fully build a recycling system in Russia or whether it should be done by manufacturers, as in the EU countries. If manufacturers have to deal with recycling, the issue of recycling imported cars remains unclear. The problem can be solved through the cooperation of producers and the State.

For a comprehensive recycling system, we should also consider the issue of the disposal of special vehicles, which should be recycled in the same way as all other vehicles. It is also important to address the issue of rail, air and water transport, which was not considered in this study, but has an impressive amount of waste and its own specifics.

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